What is claimed is:

1. A method for efficient convolution, comprising the steps of:

preparing a plurality of segmented perceptual response frequency spectra by removing high frequency components from a plurality of segmented response frequency spectra;

generating a plurality of segmented input frequency spectra from a plurality of segmented input signals; and

performing a frequency domain convolution method to generate convoluted signals using said plurality of segmented perceptual response frequency spectra and said plurality of segmented input frequency spectra;

wherein said plurality of segmented perceptual response frequency spectra are generated by removing high frequency components from said plurality of segmented response frequency spectra based on a threshold.

2. The method for efficient convolution as claimed in claim 1, wherein said efficient convolution is used for generating artificial room reverberation and said threshold is based on a threshold in quiet, said threshold being determined by the minimum amount of energy in a pure tone detected by a human hearing system in a noiseless environment.

3. The method for efficient convolution as claimed in claim 1, wherein said frequency domain convolution method is an overlap-and-add method by using FFT.

4. The method for generating efficient convolution as claimed in claim 1, wherein said frequency domain convolution method is an overlap-and-save method by using FFT.

5. The method for efficient convolution as claimed in claim 1, wherein said segmented input signals have a segment size for segmentation and in the step of performing a frequency domain convolution method to generate convoluted signals, first and second segments of convoluted signals are generated by convolution using a block size smaller than the segment size.

6. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n+sN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $s = 0, 1, 2, \ldots, M\text{-}1$;

transforming said $M$ segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented frequency spectra $H_s[k]$ with $0 \le k < 2N$;

removing high frequency components from said $M$ segmented frequency spectra $H_s[k]$ based on a threshold to form $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n+rN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $r = 0, 1, 2, \ldots, \infty$;

transforming each segmented input signal $x_r[n]$ by DFT to form a segmented input frequency spectrum $X_r[k]$;

multiplying said segmented input frequency spectrum $X_r[k]$ with said $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$ for $s = 0, 1, 2, \ldots, M\text{-}1$ to form $M$ segmented output frequency spectra $Y_{r,s}[k] = X_r[k] \cdot H'_s[k]$;

inverse transforming said $M$ output frequency spectra $Y_{r,s}[k]$ to form $M$ segmented output signals $y_{r,s}[n]$; and

performing overlap-and-add summation of said $M$ segmented output signals $y_{r,s}[n]$ to form a final output signal $y[n]$ according to

$$y[n] = \sum_{r=0}^{\infty} \sum_{s=0}^{M-1} y_{r,s}[n - rN - sN].$$

7. The method for efficient convolution according to claim 6, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

8. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n+sN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $s = 0, 1, 2, \ldots, M\text{-}1$;

transforming said $M$ segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented frequency spectra $H_s[k]$ with $0 \le k < 2N$;

removing high frequency components from said $M$ segmented frequency spectra $H_s[k]$ based on a threshold to form $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n+rN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $r = 0, 1, 2, \ldots, \infty$;

transforming each segmented input signal $x_r[n]$ by FFT to form a segmented input

frequency spectrum $X_r[k]$;

buffering said segmented input frequency spectrum to form buffered segmented input frequency spectra $X_{p-s}[k]$ for $s = 0, 1, 2, \ldots, M$ and $p = 0, 1, 2, \ldots, \infty$;

multiplying said $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$ with last buffered $M$ segmented input frequency spectra $X_{p-s}[k]$ to form products $X_{p-s}[k] \cdot H'_s[k]$ for $s = 0, 1, 2, \ldots, M-1$ and adding said products together to form a segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X_{p-s}[k] H'_s[k], \text{ for } 0 \le k < 2N-1;$$

inverse transforming said segmented output frequency spectrum $Y_p[k]$ to form segmented output signals $y_p[n]$; and

performing overlap-and-add summation of said $M$ segmented output signals $y_p[n]$ to form a final output signal $y[n]$ according to

$$y[n] = \sum_{p=s}^{\infty} y_p[n].$$

9. The method for efficient convolution according to claim 8, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

10. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$ of ;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n + sN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $s = 0, 1, 2, \ldots, M\text{-}1$;

transforming said segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented frequency spectra $H_s[k]$ with $0 \leq k < 2N$;

removing high frequency components from said segmented frequency spectra $H_s[k]$ based on a threshold to form $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n+rN], & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases}$ , $r = 0, 1, 2, \ldots, \infty$;

overlapping and adding adjacent segmented input signals to form a plurality of overlapped-and-segmented input signals $x'_p[n] = x_{p-1}[n+N] + x_p[n]$, wherein $-N \leq n \leq N-1$ and $p = 0, 1, 2, \ldots, \infty$;

transforming each overlapped-and-segmented input signal $x'_p[n]$ by FFT to form a segmented input frequency spectrum $X'_p[k]$;

buffering said segmented input frequency spectrum to form buffered segmented input frequency spectra $X'_{p-s}[k]$ for $s = 0, 1, 2, \ldots, M$ and $p = 0, 1, 2, \ldots, \infty$;

multiplying said $M$ sets of segmented perceptual response frequency spectra $H'_s[k]$ with last buffered $M$ segmented input frequency spectra $X'_{p-s}[k]$ to form products $X'_{p-s}[k] \cdot H'_s[k]$ for $s = 0, 1, 2, \ldots, M-1$ and adding said products together to form a segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X'_{p-s}[k] H'_s[k], \text{ for } 0 \leq k < 2N-1;$$

inverse transforming said segmented output frequency spectrum $Y_p[k]$ to form segmented output signals $y_p[n]$; and

generating a final output signal $y$[n] by discarding first $N$ samples of $y_p[n]$.

11. The method for efficient convolution according to claim 10, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

12. An apparatus for efficient convolution, comprising:

a plurality of perceptual sparse processing units for removing high frequency components from a plurality of segmented response frequency spectra to form a plurality of segmented perceptual response frequency spectra; and

a FIR-filter receiving said plurality of segmented perceptual response frequency spectra;

wherein each of said perceptual sparse processing units removes high frequency components from a segmented response frequency spectrum based on a threshold.

13. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR filter is implemented by a frequency domain convolution method based on an overlap-and-add method.

14. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR-filter is implemented by a frequency domain convolution method based on an overlap-and-save method.

15. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR-filter comprises a first section in which frequency domain convolution is computed with a first block size for reducing latency and a second section in which frequency domain convolution is computed with a second block size.

16. An apparatus for efficient convolution, comprising:

a segmenting unit for segmenting an input signal into segmented input signals;

a FFT processor for performing fast Fourier transform on each segmented input signal to a segmented input frequency spectrum;

a plurality of perceptual sparse processing units for removing high frequency components from a plurality of segmented response frequency spectra to form a plurality of segmented perceptual response frequency spectra;

a plurality of memory devices for storing said plurality of segmented perceptual response frequency spectra;

a plurality of multipliers for multiplying said segmented input frequency spectrum with said plurality of segmented perceptual response frequency spectra to form a plurality of segmented output frequency spectra;

a plurality of IFFT processors for performing inverse fast Fourier transform on said plurality of segmented output frequency spectra to form a plurality of segmented output signals; and

a plurality of overlap-and-add units for overlapping and adding said plurality of segmented output signals to form a final output signal;

wherein each of said perceptual sparse processing units removes high frequency components from a segmented response frequency spectrum based on a threshold.

17. An apparatus for efficient convolution, comprising:

a segmenting unit for segmenting an input signal into segmented input signals;

a FFT processor for performing fast Fourier transform on each segmented input signal to a segmented input frequency spectrum;

a plurality of perceptual sparse processing units for removing high frequency components from a plurality of segmented response frequency spectra to form a plurality of segmented perceptual response frequency spectra;

a plurality of memory devices for storing said plurality of segmented perceptual response frequency spectra;

a plurality of buffers for buffering a plurality of segmented input frequency spectra;

a plurality of multipliers for multiplying said buffered plurality of segmented input frequency spectra with said plurality of segmented perceptual response frequency spectra to form a plurality of segmented output frequency spectra;

a summation unit for adding said plurality of segmented output frequency spectra to form an output frequency spectrum;

an IFFT processor for performing inverse fast Fourier transform on said output frequency spectrum to form an output signal; and

an overlap-and-add unit for overlapping and adding said output signal to form a final output signal;

wherein each of said perceptual sparse processing units removes high frequency components from a segmented response frequency spectrum based on a threshold .

18. An apparatus for efficient convolution, comprising:

an overlapping and segmenting unit for overlapping and segmenting an input signal

into overlapped-and-segmented input signals;

a FFT processor for performing fast Fourier transform on each overlapped-and-segmented input signal to a segmented input frequency spectrum;

a plurality of perceptual sparse processing units for removing high frequency components from a plurality of segmented response frequency spectra to form a plurality of segmented perceptual response frequency spectra;

a plurality of memory devices for storing said plurality of segmented perceptual response frequency spectra;

a plurality of buffers for buffering a plurality of segmented input frequency spectra;

a plurality of multipliers for multiplying said buffered plurality of segmented input frequency spectra with said plurality of segmented perceptual response frequency spectra to form a plurality of segmented output frequency spectra;

a summation unit for adding said plurality of segmented output frequency spectra to form an output frequency spectrum;

an IFFT processor for performing inverse fast Fourier transform on said output frequency spectrum to form an output signal; and

a discarding unit for discarding a number of samples from said output signal to form a final output signal;

wherein each of said perceptual sparse processing units removes high frequency components from a segmented response frequency spectrum based on a threshold.

19. A method for efficient convolution, comprising the steps of:

preparing a plurality of segmented response frequency spectra;

generating a plurality of segmented input frequency spectra from a plurality of segmented input signals;

removing high frequency components from said plurality of segmented input frequency spectra to form a plurality of segmented perceptual input frequency spectra; and

performing a frequency domain convolution method to generate convoluted signals using said plurality of segmented response frequency spectra and said plurality of segmented perceptual input frequency spectra;

wherein said plurality of segmented perceptual input frequency spectra are generated by removing high frequency components from said plurality of segmented input frequency spectra based a threshold.

20. The method for efficient convolution as claimed in claim 19, wherein said efficient convolution is used for generating artificial room reverberation and said threshold is based on a threshold in quiet, said threshold being determined by the minimum amount of energy in a pure tone detected by a human hearing system in a noiseless environment.

21. The method for efficient convolution as claimed in claim 19, wherein said frequency domain convolution method is an overlap-and-add method by using FFT.

22. The method for generating efficient convolution as claimed in claim 1, wherein said frequency domain convolution method is an overlap-and-save method by using FFT.

23. The method for efficient convolution as claimed in claim 19, wherein said segmented

input signals have a segment size for segmentation and in the step of performing a frequency domain convolution method to generate convoluted signals, first and second segments of convoluted signals are generated by convolution using a block size smaller than the segment size.

24. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n+sN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $s = 0, 1, 2, \ldots, M\text{-}1$;

transforming said $M$ segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented response frequency spectra $H_s[k]$ with $0 \le k < 2N$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n+rN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $r = 0, 1, 2, \ldots, \infty$;

transforming each segmented input signal $x_r[n]$ by DFT to form a segmented input frequency spectrum $X_r[k]$;

removing high frequency components from said segmented input frequency spectra $X_r[k]$ based on a threshold to a segmented perceptual input frequency spectra $X'_r[k]$;

multiplying said segmented perceptual input frequency spectrum $X'_r[k]$ with said $M$ sets of segmented response frequency spectra $H_s[k]$ for $s = 0, 1, 2, \ldots, M\text{-}1$ to form $M$ segmented output frequency spectra $Y_{r,s}[k] = X'_r[k] \cdot H_s[k]$;

inverse transforming said $M$ output frequency spectra $Y_{r,s}[k]$ to form $M$ segmented output signals $y_{r,s}[n]$; and

performing overlap-and-add summation of said $M$ segmented output signals $y_{r,s}[n]$ to

form a final output signal $y[n]$ according to

$$y[n] = \sum_{r=0}^{\infty} \sum_{s=0}^{M-1} y_{r,s}[n - rN - sN].$$

25. The method for efficient convolution according to claim 24, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

26. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n + sN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $s = 0, 1, 2, \ldots, M\text{-}1$;

transforming said $M$ segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented response frequency spectra $H_s[k]$ with $0 \le k < 2N$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n + rN], & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases}$, $r = 0, 1, 2, \ldots, \infty$;

transforming each segmented input signal $x_r[n]$ by FFT to form a segmented input frequency spectrum $X_r[k]$;

removing high frequency components from said segmented input frequency spectrum $X_r[k]$ based on a threshold to form a segmented perceptual input frequency spectrum $X'_r[k]$;

buffering said segmented perceptual input frequency spectrum to form buffered segmented perceptual input frequency spectra $X'_{p-s}[k]$ for $s = 0, 1, 2, \ldots, M$ and $p = 0,$

1, 2, …, ∞;

multiplying said $M$ sets of segmented response frequency spectra $H_s[k]$ with last buffered $M$ segmented perceptual input frequency spectra $X'_{p\text{-}s}[k]$ to form products $X'_{p\text{-}s}[k]\cdot H_s[k]$ for $s$ = 0, 1, 2, …, $M$–1 and adding said products together to form a segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X'_{p-s}[k] H_s[k], \text{ for } 0 \leq k < 2N\text{–}1;$$

inverse transforming said segmented output frequency spectrum $Y_p[k]$ to form segmented output signals $y_p[n]$; and

performing overlap-and-add summation of said $M$ segmented output signals $y_p[n]$ to form a final output signal $y[n]$ according to

$$y[n] = \sum_{p=s}^{\infty} y_p[n].$$

27. The method for efficient convolution according to claim 26, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

28. A method for efficient convolution, comprising the steps of:

preparing an impulse response $h[n]$ of ;

segmenting said impulse response into $M$ segmented impulse responses $h_s[n]$, wherein $h_s[n] = \begin{cases} h[n+sN], & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases}$ , $s$ = 0, 1, 2, …, $M$-1;

transforming said segmented impulse responses $h_s[n]$ by DFT to form $M$ segmented response frequency spectra $H_s[k]$ with $0 \leq k < 2N$;

receiving and segmenting an input signal $x[n]$ into a plurality of segmented input signals $x_r[n]$, wherein $x_r[n] = \begin{cases} x[n+rN], & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases}$, $r = 0, 1, 2, \ldots, \infty$;

overlapping and adding adjacent segmented input signals to form a plurality of overlapped-and-segmented input signals $x'_p[n] = x_{p-1}[n+N] + x_p[n], -N \leq n \leq N-1$;

transforming each overlapped-and-segmented input signal $x'_p[n]$ by FFT to form a segmented input frequency spectrum $X'_p[k]$;

removing high frequency components from said segmented input frequency spectrum $X'_p[k]$ based on a threshold to form a segmented perceptual input frequency spectrum $X''_p[k]$;

buffering said segmented perceptual input frequency spectrum to form buffered segmented perceptual input frequency spectra $X''_{p-s}[k]$ for $s = 0, 1, 2, \ldots, M$ and $p = 0, 1, 2, \ldots, \infty$;

multiplying said $M$ sets of segmented response frequency spectra $H_s[k]$ with last buffered $M$ segmented perceptual input frequency spectra $X''_{p-s}[k]$ to form products $X''_{p-s}[k] \cdot H_s[k]$ for $s = 0, 1, 2, \ldots, M-1$ and adding said products together to form a segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X''_{p-s}[k] H_s[k], \text{ for } 0 \leq k < 2N-1;$$

inverse transforming said segmented output frequency spectrum $Y_p[k]$ to form segmented output signals $y_p[n]$; and

generating a final output signal $y[n]$ by discarding first $N$ samples of $y_p[n]$.

29. The method for efficient convolution according to claim 28, wherein said impulse response has a length $L$ and $M = \left\lceil \frac{L}{N} \right\rceil$ is a smallest integer larger than $L$ divided by $N$.

30. An apparatus for efficient convolution, comprising:

a segmenting unit for segmenting an input signal into segmented input signals;

a FFT processor for performing fast Fourier transform on each segmented input signal to a segmented input frequency spectrum;

a perceptual sparse processing unit for removing high frequency components from said segmented input frequency spectrum to form a segmented perceptual input frequency spectrum;

a plurality of memory devices for storing a plurality of segmented response frequency spectra;

a plurality of multipliers for multiplying said segmented perceptual input frequency spectrum with said plurality of segmented response frequency spectra to form a plurality of segmented output frequency spectra;

a plurality of IFFT processors for performing inverse fast Fourier transform on said plurality of segmented output frequency spectra to form a plurality of segmented output signals; and

a plurality of overlap-and-add units for overlapping and adding said plurality of segmented output signals to form a final output signal;

wherein said perceptual sparse processing unit removes high frequency components

from said segmented input frequency spectrum based on a threshold.

31. An apparatus for efficient convolution, comprising:

a segmenting unit for segmenting an input signal into segmented input signals;

a FFT processor for performing fast Fourier transform on each segmented input signal to a segmented input frequency spectrum;

a perceptual sparse processing unit for removing high frequency components from said segmented input frequency spectrum to form a segmented perceptual input frequency spectrum;

a plurality of memory devices for storing a plurality of segmented response frequency spectra;

a plurality of buffers for buffering a plurality of said segmented perceptual input frequency spectra;

a plurality of multipliers for multiplying said buffered plurality of segmented perceptual input frequency spectra with said plurality of segmented response frequency spectra to form a plurality of segmented output frequency spectra;

a summation unit for adding said plurality of segmented output frequency spectra to form an output frequency spectrum;

an IFFT processor for performing inverse fast Fourier transform on said output frequency spectrum to form an output signal; and

an overlap-and-add unit for overlapping and adding said output signal to form a final output signal;

wherein said perceptual sparse processing unit removes high frequency components from said segmented input frequency spectrum based on a threshold.

32. An apparatus for efficient convolution, comprising:

an overlapping and segmenting unit for overlapping and segmenting an input signal into overlapped-and-segmented input signals;

a FFT processor for performing fast Fourier transform on each overlapped-and-segmented input signal to a segmented input frequency spectrum;

a perceptual sparse processing unit for removing high frequency components from said segmented input frequency spectrum to form a segmented perceptual input frequency spectrum;

a plurality of memory devices for storing a plurality of segmented response frequency spectra;

a plurality of buffers for buffering a plurality of said segmented perceputal input frequency spectra;

a plurality of multipliers for multiplying said buffered plurality of segmented perceputal input frequency spectra with said plurality of segmented response frequency spectra to form a plurality of segmented output frequency spectra;

a summation unit for adding said plurality of segmented output frequency spectra to form an output frequency spectrum;

an IFFT processor for performing inverse fast Fourier transform on said output frequency spectrum to form an output signal; and

a discarding unit for discarding a number of samples from said output signal to form a final output signal;

wherein said perceptual sparse processing unit removes high frequency components from said segmented input frequency spectrum based on a threshold.